**Approach for calculating an environmental exposure metric
in an East Liverpool, Ohio Study Population**

Purpose: This brief is intended to provide information on a proposed strategy for calculating individual exposure matrices for participants in the East Liverpool, Ohio ("An Epidemiologic Health Study of Manganese Exposure in adult residents of East Liverpool, Ohio.") This approach is detailed here for the purposes of discussion with experts in exposure assessment and ambient air modeling.

Problem: Twelve years of measured environmental data are available in E. Liverpool at three locations in the community. They include: 1. The Waterplant site (adjacent to emissions source facility); 2. The Port Authority site (adjacent to the WTI waste incinerator site); and 3. The Maryland Avenue site (adjacent to the former East Elementary School and one block from WTI). No ambient air data or personal sampling data are available to assess individual exposures, thus a method for estimating individual exposures is necessary for conducting analyses with health outcome data.

Approach: The approach for estimating individual exposures are outlined in the following steps:

1. Understanding receptor point exposure relationships
Identify the relationship between the location of the residence and general risk of exposure:
Although we did not have individual exposure data, we needed to determine the relational exposure of each residence to a reference point. We chose the reference point to be the Waterplant monitor site (which has historically had the highest measured concentrations of ambient metals in the area). The Waterplant monitor site is across the street from the emissions source facility property. The Waterplant monitor site also has the longest history of discrete analysis on filters (since 2005; other sites began having discrete analyses in 2011).

To assist in calculating the relational exposure, we used AERMOD to estimate exposure from some generic emission rate over the surface area of the emissions source facility at a constant emission rate of 1 gram per second over the entire 42 acre property (186,155 m^2). The nearest and most representative meteorological station is located at the Pittsburgh International Airport in Pittsburgh, PA, which is approximately 25 miles southeast of the facility. NCDC surface data, NWS surface data, and NWS upper air data are all available for this station, and five consecutive years of data (2006-2010) were processed through AERMET. Onsite meteorological data was available at the monitoring station nearest the emissions source facility; however, the data contained numerous hours with exceptionally high wind speeds that called the entire dataset into question. Because the accuracy of data could not be verified, it was not included in the analysis[1].

For the purposes of this study, the ambient estimates from the modeling are irrelevant, but their relation to each other and the reference point are useful for calculating estimated exposures. We calculated ratios of all receptor points to the reference point (ratio=1) at the Waterplant monitor site. Topography, distance, and meteorology were incorporated into the model.

We calibrated the modeled ratios with actual monitored manganese data. The Port Authority and Maryland Avenue sites had roughly similar modeled ratios in comparison to the Waterplant monitor site

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[1] USEPA. Cooperative Agreement Modeling Report S.H. Bell East Liverpool, Ohio. Chicago, IL: February 13, 2012.

(3.1% and 2.3%, respectively), but based on monitoring, the ratios are actually higher (28% and 25%, respectively (rounded)). Since the Port Authority and Maryland Avenue monitor sites are each approximately 1.25 miles to the west-southwest from the emissions source facility and Waterplant monitor site, this similarity is expected. Given the modeled ratios defining the relationship of receptor points to each other and the reference location, we adjusted the ratios based on measured data. Thus, the average ratio of discrete data from the Port Authority and Maryland Avenue monitor sites to the Waterplant monitor site was 26.6%; all ratios were adjusted upward based on this revised ratio. Although this adjustment was not necessary to understand who is likely to be most impacted in the study, it was necessary for the purposes of estimating realistic annual exposures.

The measured ambient ratios for the Port Authority and Maryland Avenue monitor sites to the Waterplant monitor site were calculated using discrete data from 2011, the only year when discrete samples were collected at all monitoring locations. We also calculated ratios from the historical monthly composite data (21% and 12%, respectively), but noted a general underestimation of actual conditions using composite data (for example, on average, between 2005 and 2011 Waterplant monitor site annual averages based on composite data underestimate the annual discrete average by 15.6%).

2. Calculating annual estimated exposures at receptor points
The revised ratios were used to calculate annual estimated exposures for each of the years 2005-2011, when discrete data are available from the Waterplant monitor site. For years prior to the collection of discrete data, composite annual averages were adjusted up by 15.6% (this adjustment is based on the underestimate in annual concentrations noted between discrete and composite data as discussed, above), and annual averages were calculated from 1999-2004 for each receptor point from revised ratios.

3. Assumptions of exposure prior to 1999, when Mn began being collected in the community
Annual production records for the emissions source facility have been requested. Data for other metals have been collected in the area since 1991. We plan to estimate historical manganese concentrations based on correlations with other metals in our 12-year dataset or by relationships determined between production and measured manganese in ambient air since 1999. To the best of our ability, we will estimate exposures back to 1963, when the emissions source facility began operations.

4. Uncertainties[2]

Modeling:
1) This analysis is not an exposure analysis, as it does not take activity patterns or other variables into account; however, modeled long-term average concentrations can be used for a conservative surrogate for inhalation exposure. This assumes that a person is exposed to these modeled concentrations for 24 hours a day for 70 years, which is likely to overestimate the actual exposure.

2) Dispersion models are better at predicting the maximum expected values in a general area, but they are somewhat limited in their ability to determine a specific concentration at a specific location. This uncertainty could over- or under-predict the ambient concentrations.

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[2] USEPA. Cooperative Agreement Modeling Report S.H. Bell East Liverpool, Ohio. Chicago, IL: February 13, 2012.

3) Due to the lack of facility-specific information, the source parameters and emission rates for the facility were based entirely on generic assumptions.   First, it was assumed that the annual emission rate, as calculated in tons per year, would be emitted equally in grams per second per meter squared over the entire year. This is unlikely to be the case, but we have no basis for allocating variable emissions, and this is standard modeling procedure. Specific processes at the facility were not taken into account, and a unit emission rate was used. This could over- or under-predict the facility's ambient impact on the annual average.

5) Building dimensions for use in the Building Profile Input Program (BPIP) preprocessor were not included in this modeling study.   BPIP determines whether stacks are being subjected to wake effects from structures and calculates building heights and projected building widths to determine if there is any resulting building downwash. Generally, the use of BPIP increases concentrations near the fenceline; thus, this may under-predict concentrations closer to the facility fenceline.

Estimated Annual Exposures:

1) Without further data, we assume the discrete ambient ratios for 2011 apply to all prior years. Although actual conditions may vary, we felt the higher resolution of the discrete data from 2011 was more useful than composite data, which tended to underestimate annual averages compared to discrete data. Also, historical conditions were likely to have resulted in higher exposures since less engineering controls were required. Thus, biasing the concentrations higher using the discrete ratios over the composite ratios is warranted in order to be inclusive of worst case exposure scenarios.

2) We will be reconstructing historical exposure prior to 1999 using production records (if they become available) and making assumptions of ambient Mn based on its relationship to other ambient metals released from the emissions source facility.